Status Report from NNPDF

Juan Rojo

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Dipartimento di Fisica, Università di Milano

DIS 2011 workshop, Newport News, VA, 12/04/2011

Outline

In this talk:

- Towards NNLO NNPDFs and NNLO Higgs production
- The impact of NMC data in Higgs production
- Precision NLO determination of $\alpha_S\left(M_Z^2\right)$ from NNPDF2.1

In the afternoon talk (Joint SF+EWK session):

- The Tevatron lepton asymmetry data and PDFs
- PDFs with LHC data: the impact of CMS, ATLAS and LHCb W lepton asymmetry measurements

In tomorrow's talk (Joint SF+HQ session):

- The impact of heavy quark mass effects on PDFs
- Implications for LHC phenomenology

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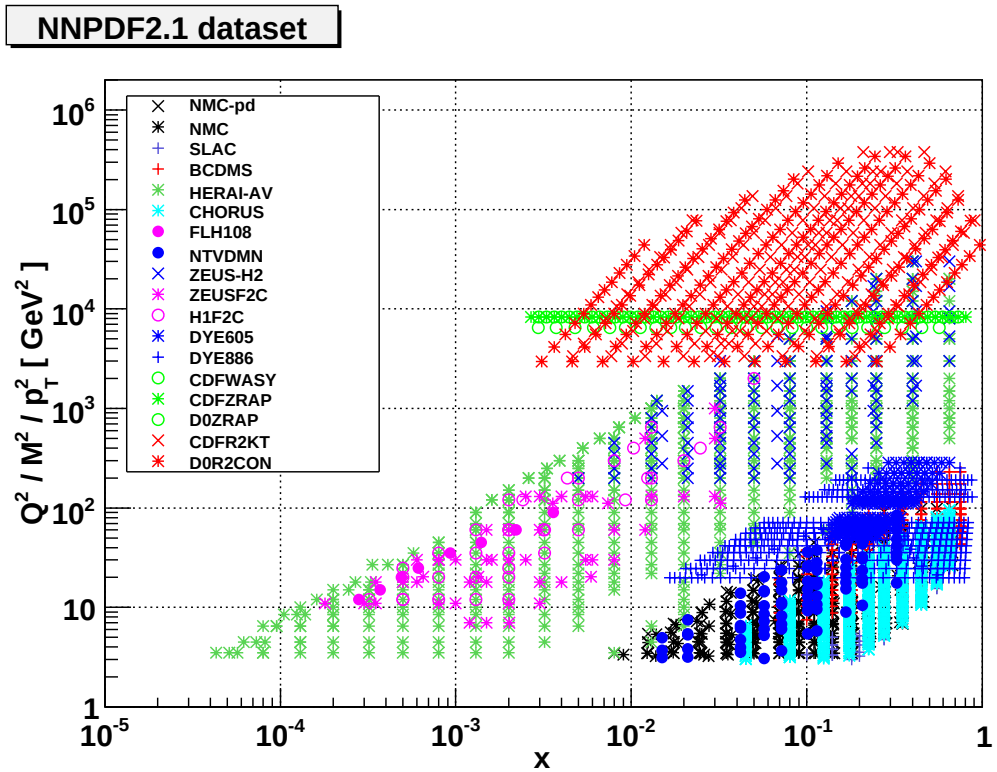
THE NNPDF2.1 NNLO SET: FIRST (PRELIMINARY) RESULTS

NNPDF@NNLO

- NNPDF2.1 NNLO: (preliminary) unbiased NNLO global analysis
- Same dataset as in NNPDF2.1 NLO (arXiv:1101.1300, NPB in press).

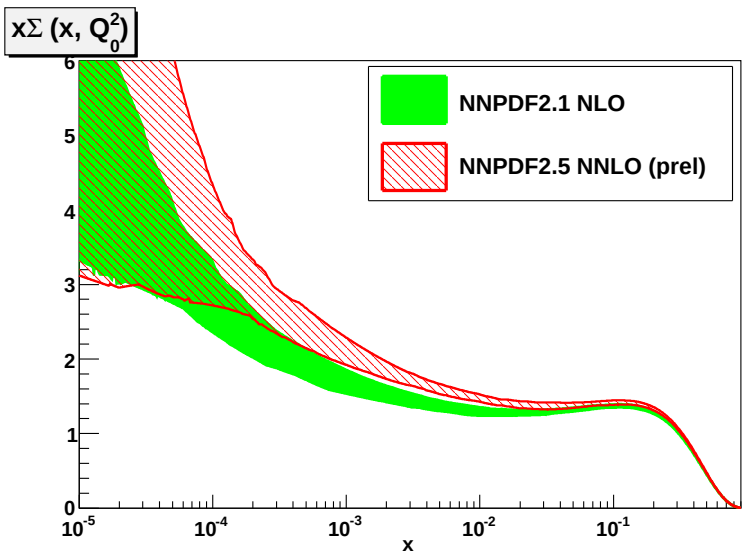


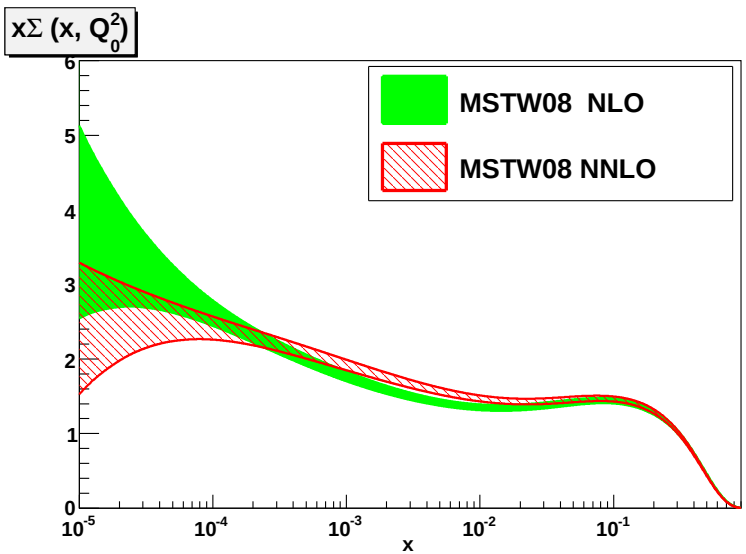
NNPDF2.1: **Global Analysis**

1. Fixed Target DIS
2. Combined HERA–I data, HERA F_2^c
3. Fixed Target DY
4. Tevatron W and Z production
5. Tevatron jet production
6. (LHC W lepton asymmetry)

NNPDF@NNLO

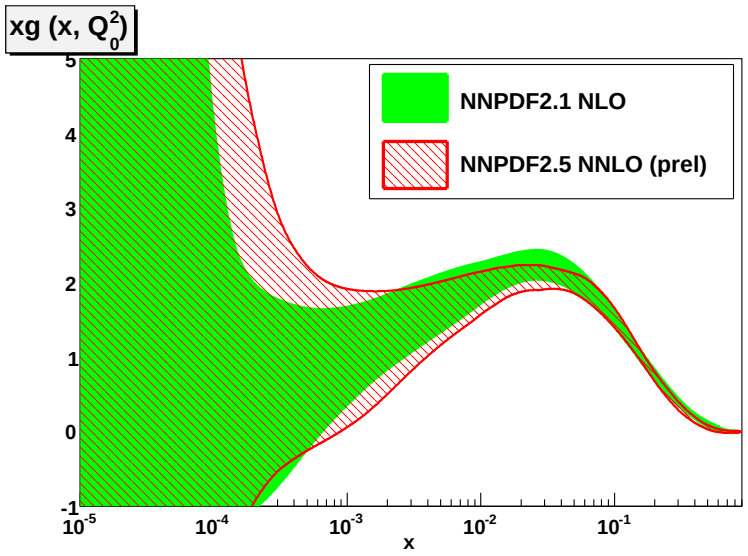
- NNPDF2.1 NNLO: (preliminary) unbiased NNLO global analysis
- Same dataset as in NNPDF2.1 (arXiv:1101.1300). FONLL-C for DIS structure functions
- Impact of NNLO: Harder small-x sea quarks (same trend as MSTW08)

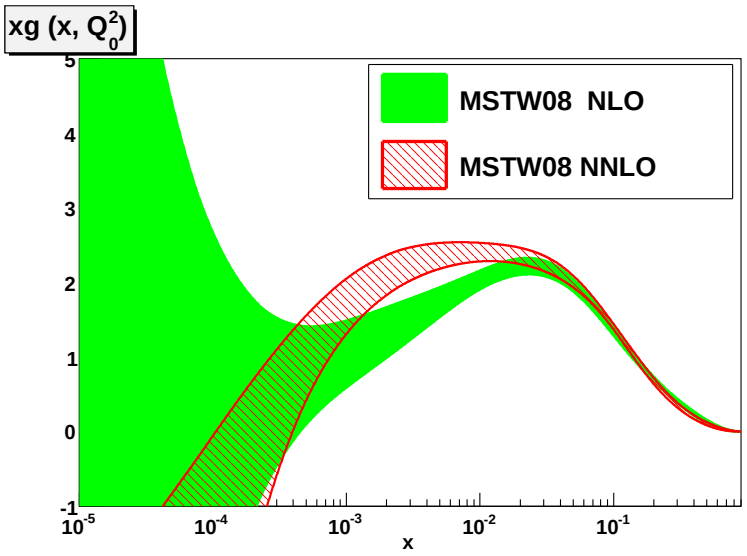




NNPDF@NNLO

- NNPDF2.1 NNLO: (preliminary) NNLO global analysis
- Same dataset as in NNPDF2.1, FONLL-C for DIS structure functions
- Impact of NNLO: Stable small-x gluons (opposite to MSTW08)
  N. B. MSTW08 NLO and NNLO with different α_s values





NNLO NNPDFs almost ready for LHC phenomenology

NNPDF@NNLO

- NNPDF2.1 NNLO: (preliminary) NNLO global analysis
- Same dataset as in NNPDF2.1 (arXiv:1101.1300, NPB in press). FONLL-C for DIS structure functions
- Impact of NNLO: Central values shift by $\leq 1, 1.5$–σ, PDF uncertainties unchanged

Statistical distances:

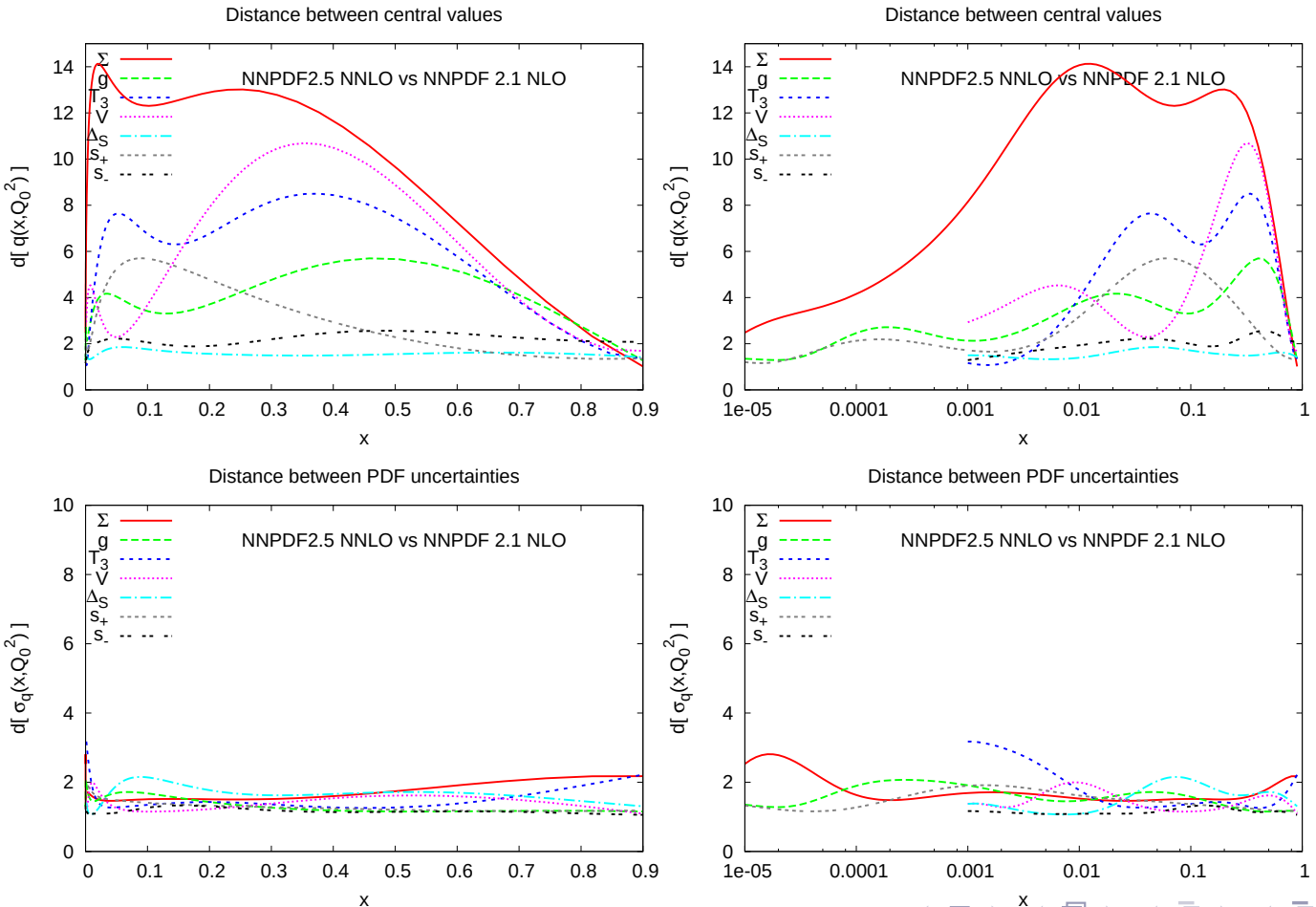
$$\langle q^{(k)}\rangle_{(i)} = \frac{1}{N^{(i)}_{\rm rep}}\sum_{i=1}^{N^{(i)}_{\rm rep}} q_i^{(k)}. \qquad \sigma^2_{(i)}[\langle q^{(i)}\rangle] = \frac{1}{N^{(i)}_{\rm rep}}\sigma^2_{(i)}[q^{(i)}] \tag{1}$$

$$\mathbf{d^2}\left(\langle \mathbf{q^{(1)}}\rangle, \langle \mathbf{q^{(2)}}\rangle\right) = \frac{\left(\langle q^{(1)}\rangle_{(1)} - \langle q^{(2)}\rangle_{(2)}\right)^2}{\sigma^2_{(1)}[\langle q^{(1)}\rangle] + \sigma^2_{(2)}[\langle q^{(2)}\rangle]} \tag{2}$$

Distance $\mathbf{d} \sim \mathbf{1} \rightarrow$ Statistically equivalent PDF sets
Distance $\mathbf{d} \sim \sqrt{\mathbf{N_{rep}}} \rightarrow$ PDF sets consistent at 1–sigma

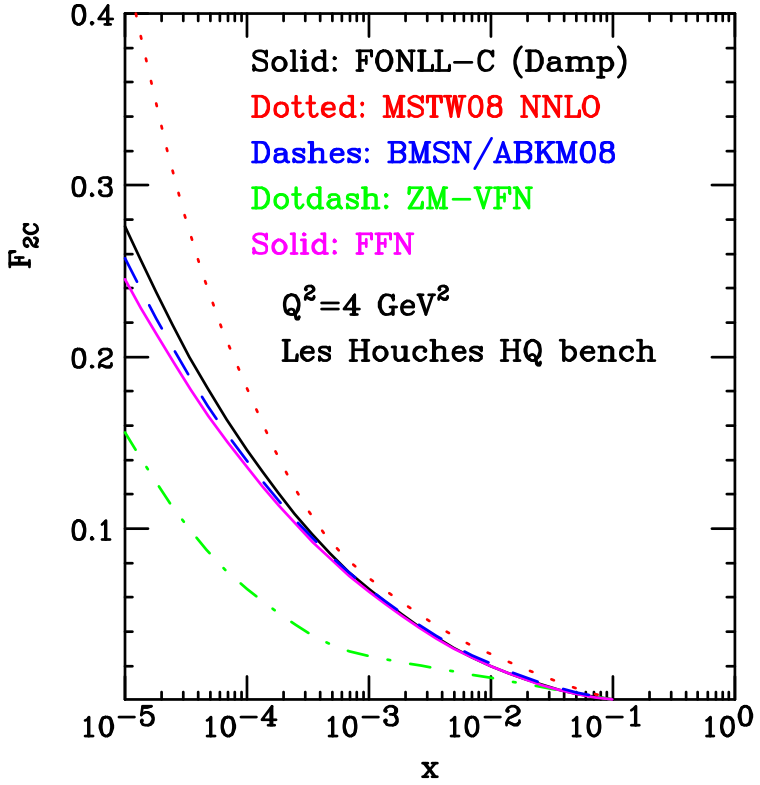
NNPDF@NNLO

- Impact of NNLO: Central values shift by $\leq 1, 1.5$–σ, PDF uncertainties unchanged

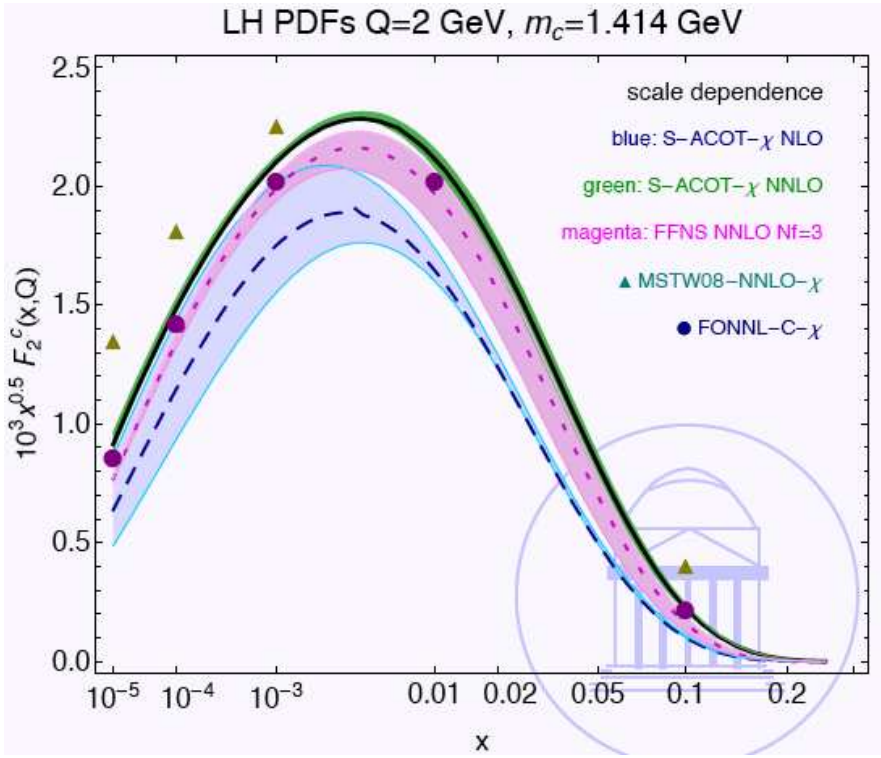


The FONLL-C GM-VFN scheme

- NNPDF2.1 NNLO based on the FONLL-C GM-VFN scheme for NNLO DIS structure functions (arxiv:1001.2312)
- S-ACOT-χ NNLO (used in CT NNLO) expected to be close FONLL-C-χ (reasonable numerical agreement)

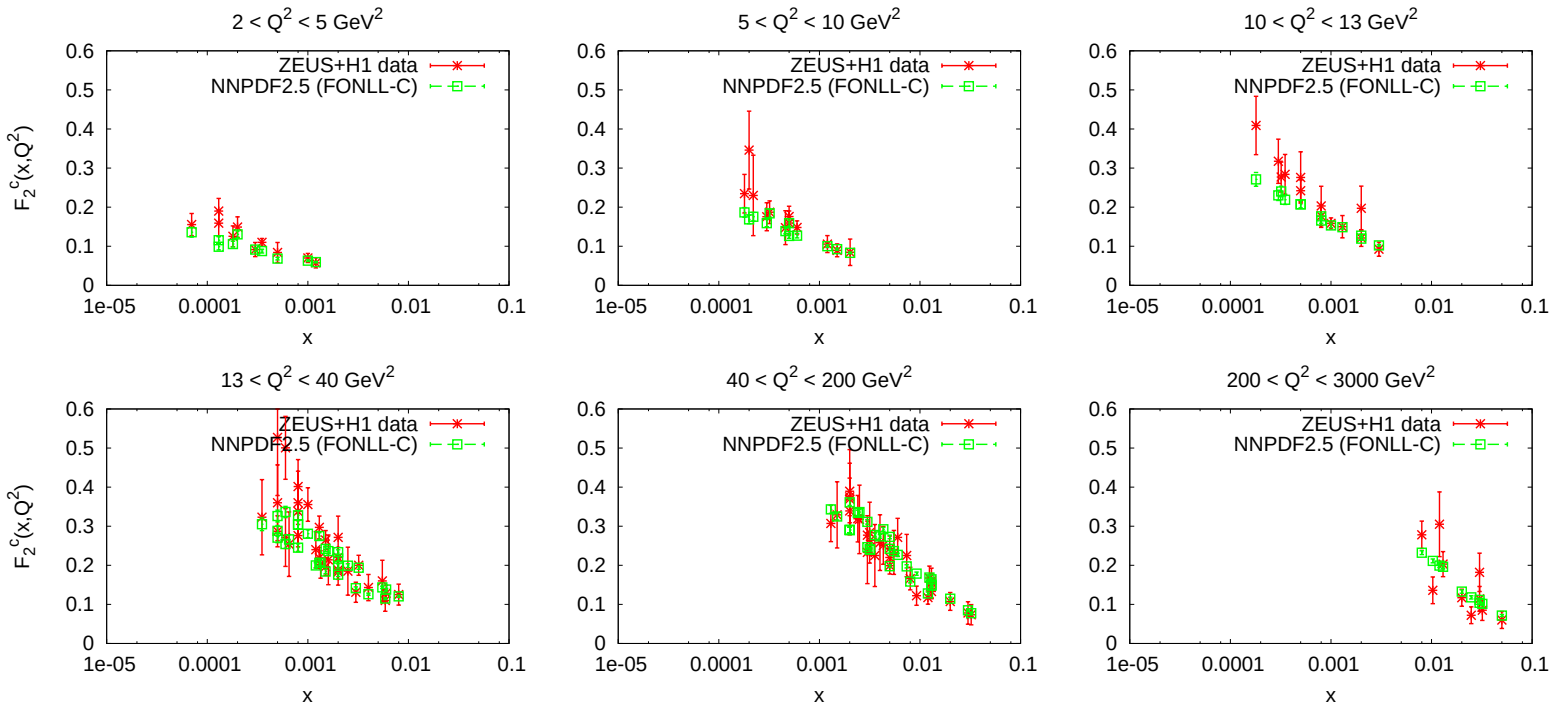


J. Rojo, LH HQ benchmarks



M. Guzzi, LH QCD 2011

HERA F_2^c data



- FONLL-C-Damp $\rightarrow$ Excellent description of ZEUS and H1 F_2^c data
- $\chi^2_{F_2^c} = 1.04$ (without any tuning of the GM-VFN)
- HERA combined F_2^c dataset $\rightarrow$ constraints for small-x gluon

The PDF4LHC working group

The PDF4LHC group (CERN management mandate) coordinates studies and research in PDF determinations from different groups and is responsible for providing official recommendations for PDF use in LHC experiments
Current NLO recommendation for LHC analysis:

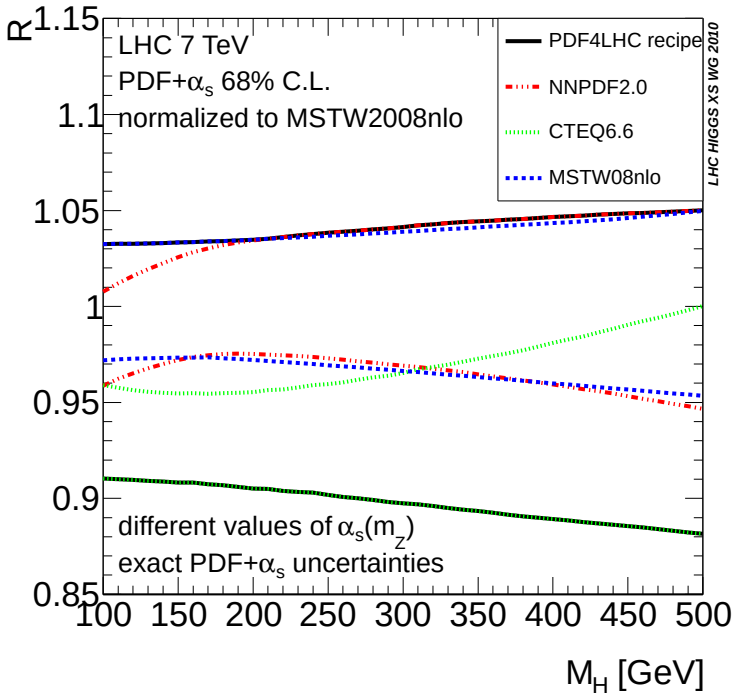
NLO Summary:

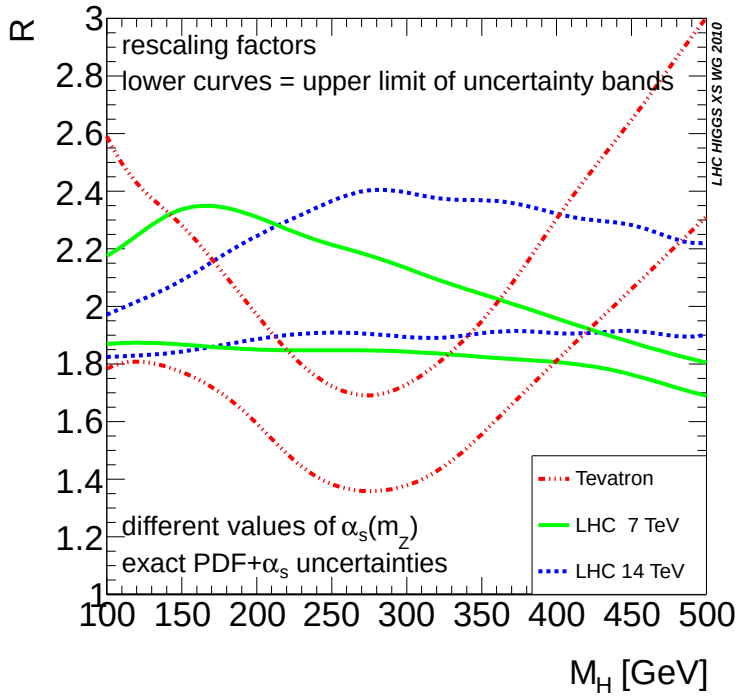
For the calculation of uncertainties at the LHC, use the envelope provided by the central values and PDF+α_s errors from the MSTW08, CTEQ6.6 and NNPDF2.0 PDFs, using each group's prescriptions for combining the two types of errors. We propose this definition of an envelope because the deviations between the predictions are currently greater than their uncertainties would strictly suggest. As a central value, use the midpoint of this

http://www.hep.ucl.ac.uk/pdf4lhc/
At NNLO: MSTW2008 NNLO central value + NLO envelope
Updated when new data / PDF sets / theoretical developements require so

The PDF4LHC recommendation and Higgs searches

PDF4LHC recommendation adopted by ATLAS, CMS and the LHC Higgs cross section working group (CERN Yellow Report, arxiv:1101.0593)

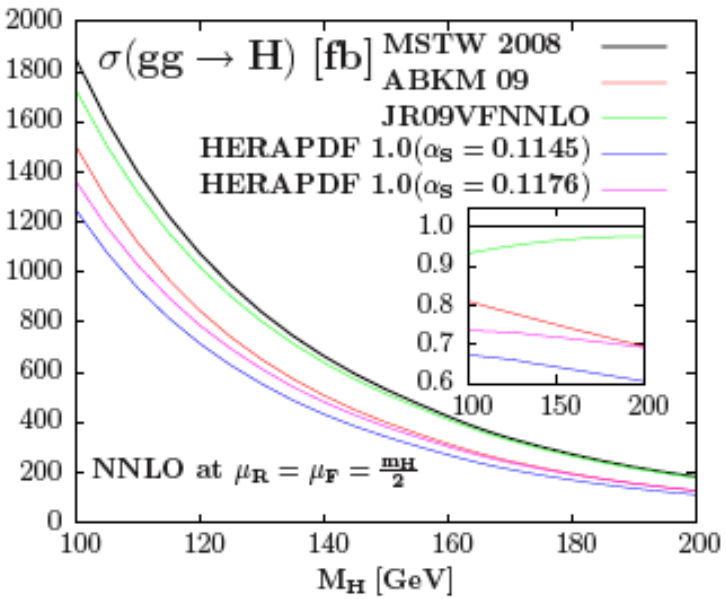


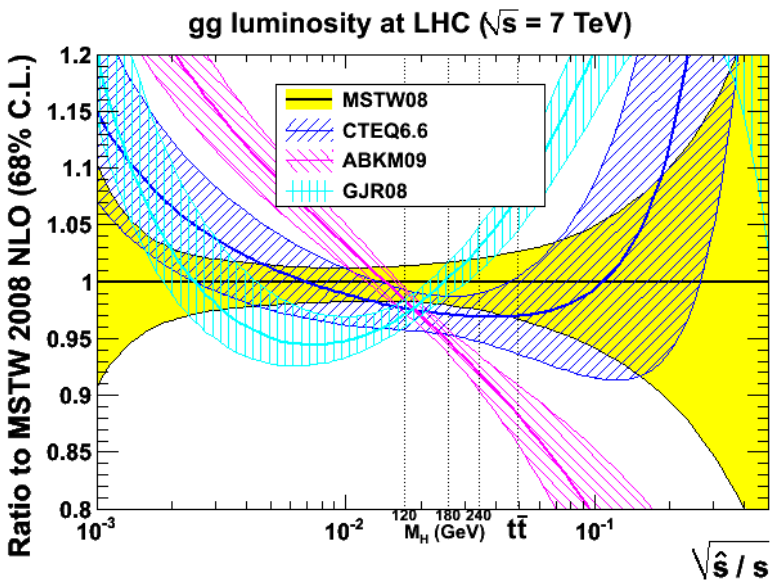


PDF4LHC recipee should be used in all LHC analysis where PDFs are relevant

PDFs and Higgs production

- The Tevatron reports SM Higgs exclusion bounds of $158 \leq M_H \leq 175$ GeV 95% C.L., theory prediction used MSTW 2008 NNLO
- Challenged by Djoaudi et al. (arXiv:1101.1832): ABKM09 and HERAPDF lead to cross sections smaller by $\sim$ 20–50% due to both smaller α_s ($\alpha_s^{\rm ABKM} = 0.1135$, $\alpha_s^{\rm MSTW} = 0.1171$) and smaller gg lumi





The Tevatron excluded mass range should be reopened?

N.B. Latest Tevatron combinationa (arXiv:1103.3233) uses PDF4LHC recipee: envelope of CTEQ6.6, MSTW08 and NNPDF2.0

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- ... ABKM09 and HERAPDF do not include Tevatron Run II jet data

χ^2 Description of CDF Run-II inclusive jet data

NNLO PDF	$\mu = p_T/2$	$\mu = p_T$	$\mu = 2p_T$
MSTW08	1.39 (0.42)	0.69 (0.44)	0.97 (0.48)
HERAPDF1.0 ($\alpha_S = 0.1145$)	2.64 (0.36)	2.15 (0.36)	2.20 (0.46)
HERAPDF1.0 ($\alpha_S = 0.1176$)	2.24 (0.35)	1.17 (0.32)	1.23 (0.31)
ABKM09	2.55 (0.82)	2.76 (0.89)	3.41 (1.17)

G. Watt, Les Houches QCD 2011

NNLO Non-global PDF sets: non–optimal description of jet data
Is the Tevatron jet data the real origin of the differences?

PDFs and Higgs production

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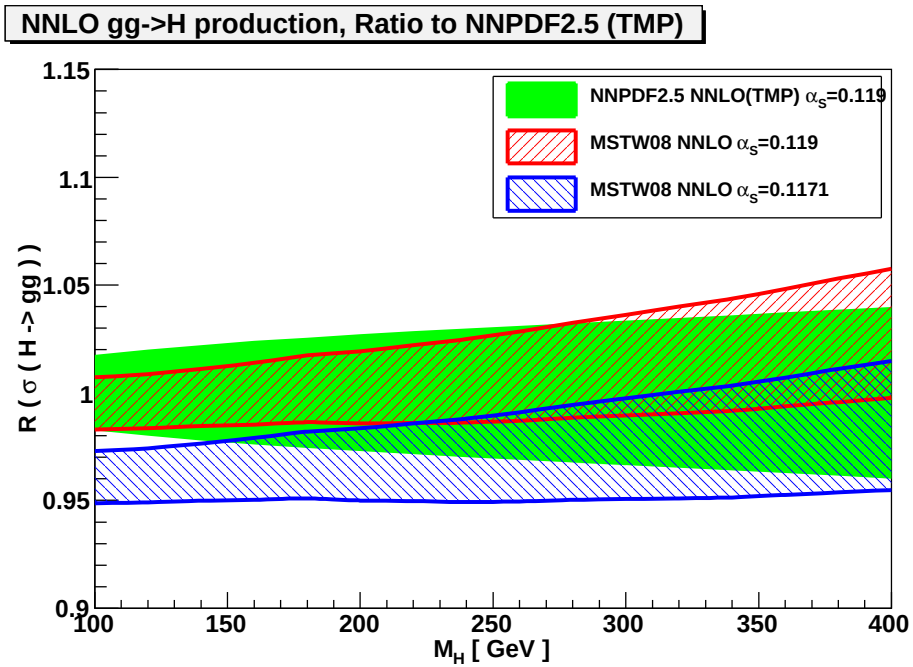
- Challenged by Djoaudi et al. (arXiv:1101.1832): ABKM09 and HERAPDF lead to cross sections smaller by $\sim$ 20–50%.
- Two NNLO global fits, MSTW08 and NNPDF2.1 NNLO, are in reasonable agreement



NNPDF2.1 NNLO/MSTW08 agree for the NNLO Higgs at $\pm 5\%$

Better agreement with common $\alpha_s\,(M_Z)$
Crucial to compare results at same α_s

Global vs. Non-Global PDF sets

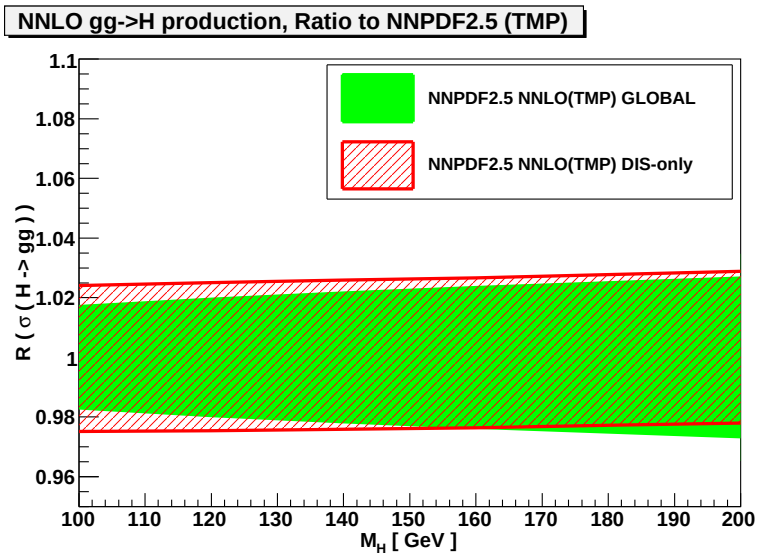
- Differences between PDF sets more subtle than *global* vs *non-global*
- NNPDF2.1 NNLO NNLO DIS–only $\rightarrow$ Excellent agreement for $\sigma(H)$ as compared to global fit
- Agreement also for Run II Tevatron jets (not included for DIS–only fit)

NNPDF DIS–only reproduces TeV jet data and agrees with global PDF predictions for $\sigma(H)$
Flexible and unbiased PDF parametrization crucial to achieve stability

Description of Tevatron Run II jets:

$$\chi^2_{\mathrm{CDF,global}} = 0.72 \qquad \chi^2_{\mathrm{CDF,dis}} = 0.81$$

$$\chi^2_{\mathrm{D0,global}} = 0.99 \qquad \chi^2_{\mathrm{D0,dis}} = 1.01$$



THE IMPACT OF NMC DATA ON PDFs AND HIGGS PRODUCTION AT HADRON COLLIDERS

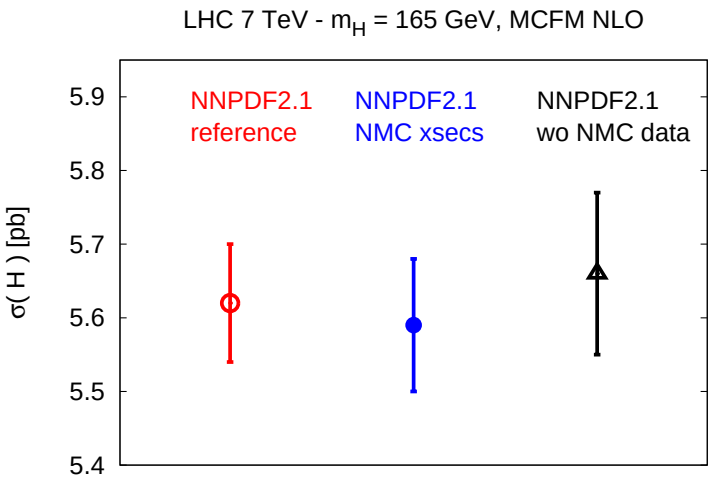
arxiv:1102.3182, submitted to PLB

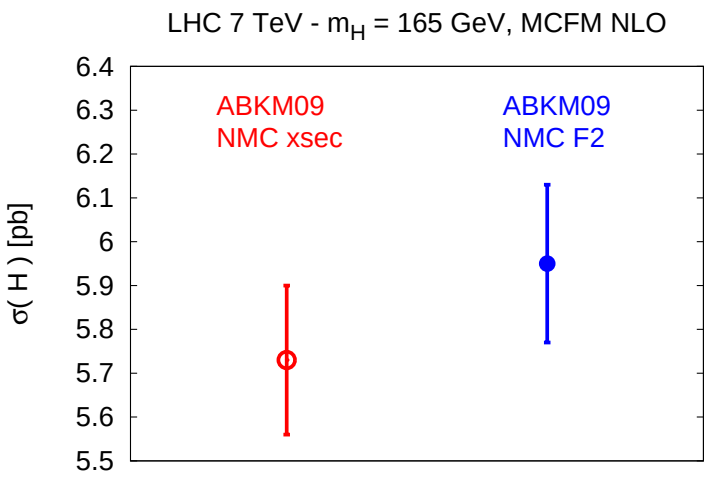
NMC data and Higgs production

- ABKM report a 3(1)–σ shift at NNLO (NLO) on the Higgs production cross section in gluon fusion at the LHC (and Tevatron) (arXiv:1101.5261)
- Claim is different treatment of fixed target DIS NMC data: used as structure functions (MSTW, NNPDF, CT) or cross sections (ABKM) $\rightarrow$ Origin of ABKM/MSTW discrepancy?

$$\widetilde{\sigma}(x, y, Q^2) = F_2(x, Q^2)\left(2 - 2y + y^2 / \left[1 + R\left(x, Q^2\right)\right]\right) + TMCs$$

- NNPDF finds negligible impact of the treatment of NMC data for Higgs production, both at NLO (arXiv:1102.3182) and at NNLO – even removing NMC altogether has moderate effect





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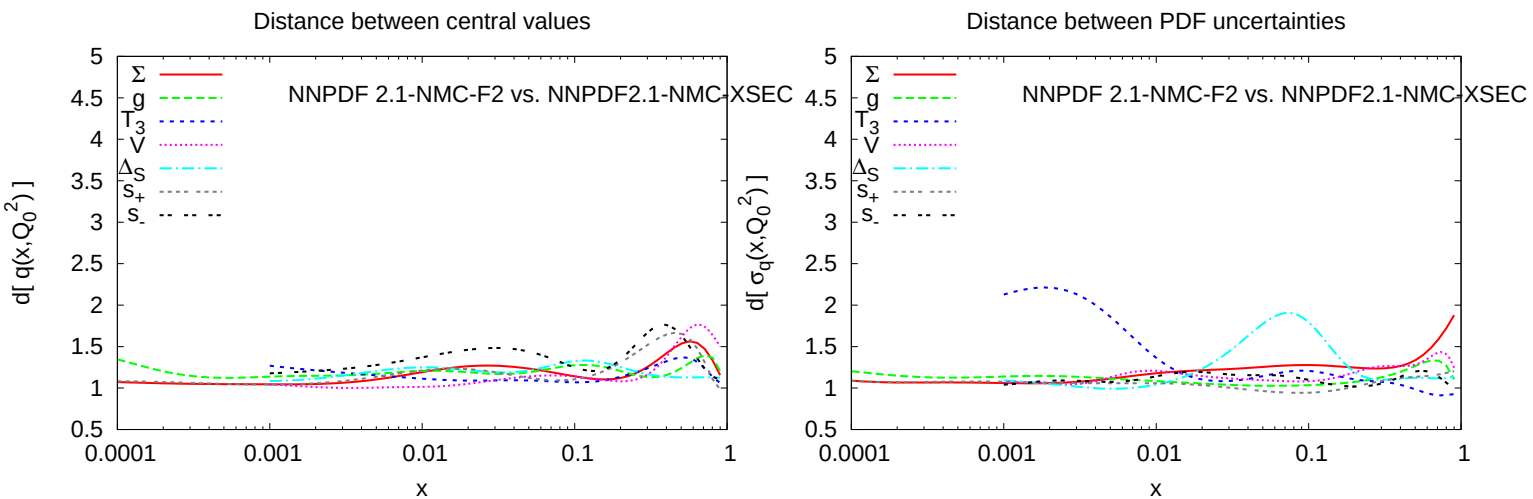

Statistical distances between NNPDF2.1 NMC-F2 and NNPDF2.1 NMC-XSEC

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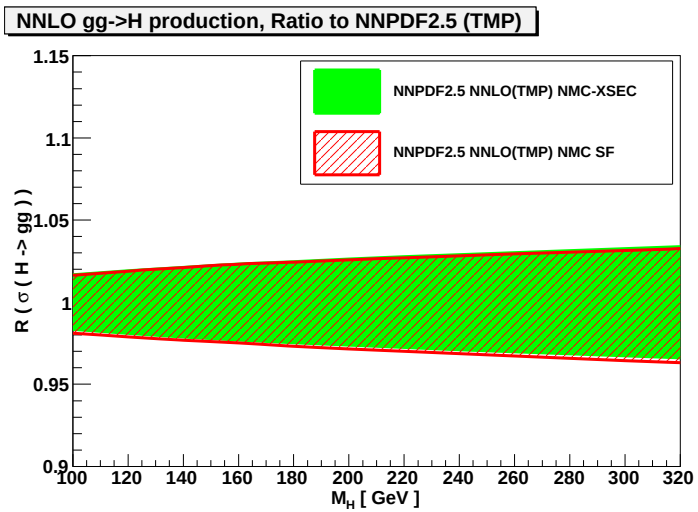

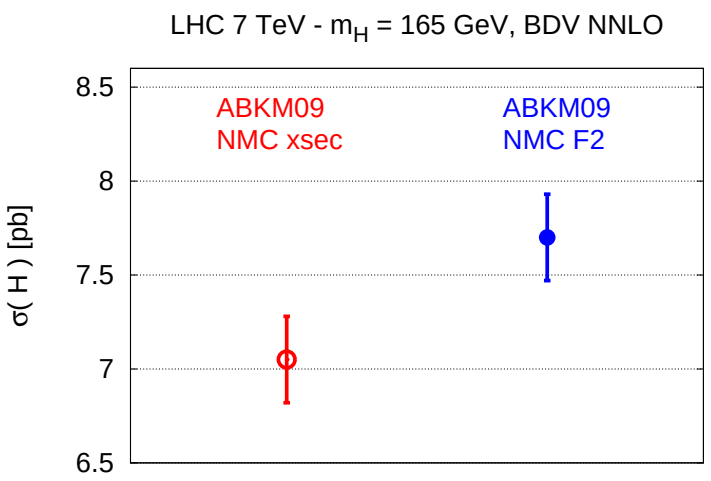

The treatment of NMC data has negligible impact on collider Higgs production
Also at NNLO

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$\alpha_s(M_Z)$	$\alpha_s(M_Z)$ with $\sigma_{\rm NMC}$	$\alpha_s(M_Z)$ with $F_2^{\rm NMC}$
NLO	0.1179(16)	0.1195(17)
NNLO	**0.1135(14)**	0.1170(15)
NNLO $+F_L$ at $O(\alpha_s^3)$	0.1122(14)	0.1171(14)

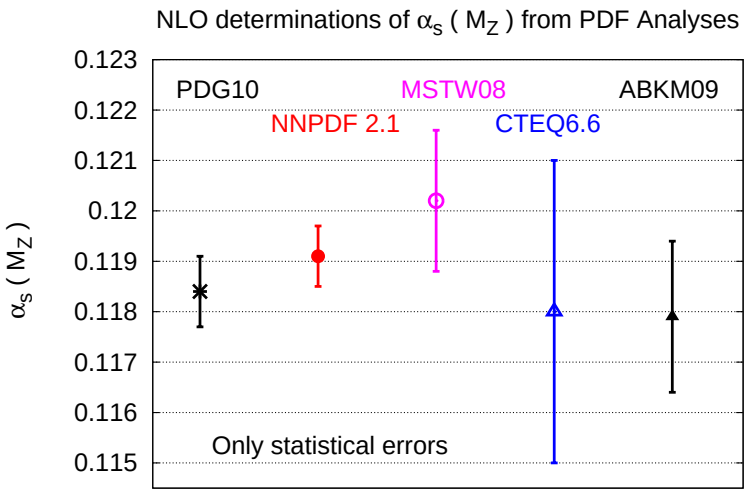
NMC *may* gave an impact on $\alpha_s(M_Z)$ determinations from PDF fits
Only affects LHC Higgs XS if PDG $\alpha_s(M_Z) = 0.1184 \pm 0.0007$ value not trusted

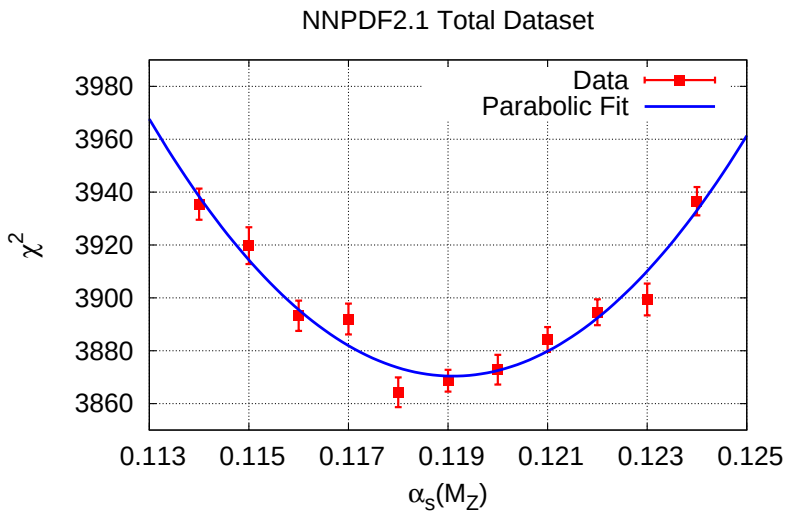
DETERMINATION OF $\alpha_s(M_Z)$ FROM AN UNBIASED GLOBAL PARTON ANALYSIS

arxiv:1103.2369, submitted to PLB

$\alpha_s(M_Z)$ from PDF analysis

- Good: Small statistical errors from large dataset
- Bad: Bias from PDF parametrization? Dependence on dataset?
- NLO: reasonable agreement, NNPDF2.1 smallest statistical uncertainty without theoretical bias
- PDG10 average: $\alpha_s^{\rm PDG}\,(M_Z) = 0.1184 \pm 0.0007$,
  $\alpha\,(M_Z)^{\tau+\rm EW} = 0.1206 \pm 0.0012$

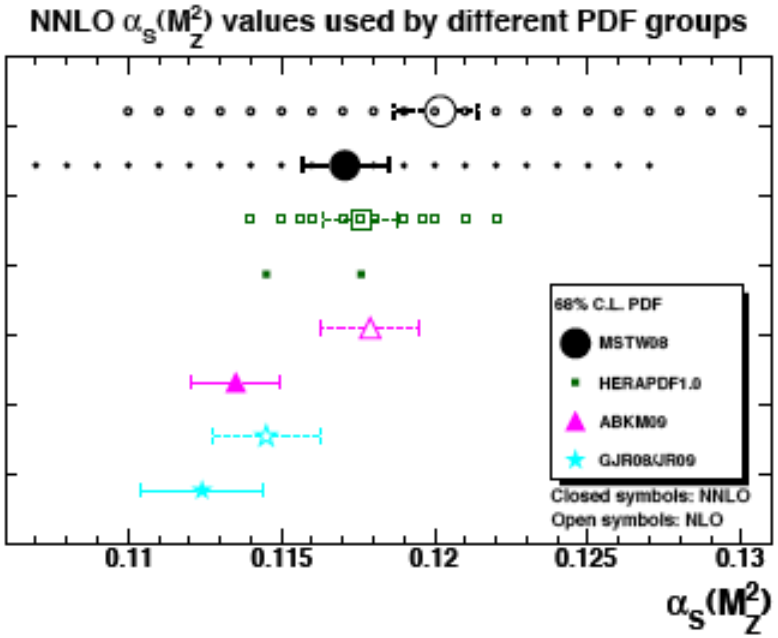




N.B.: CT, NNPDF and MSTW provide PDF sets for a wide range of $\alpha_s\,(M_Z)$ values

$\alpha_s(M_Z)$ from PDF analysis

- Good: Small statistical errors from large dataset
- Bad: Bias from PDF parametrization? Dependence on dataset?
- Large spread in NNLO α_s values from PDF fits
  $\rightarrow$ Hints of breakdown of perturbative expansion?
  $\rightarrow$ DIS not the best place to determine $\alpha_s\,(M_Z)$?
- Is it meaningful to use $\alpha_s\,(M_Z) = 0.1135$ in LHC phenomenology?

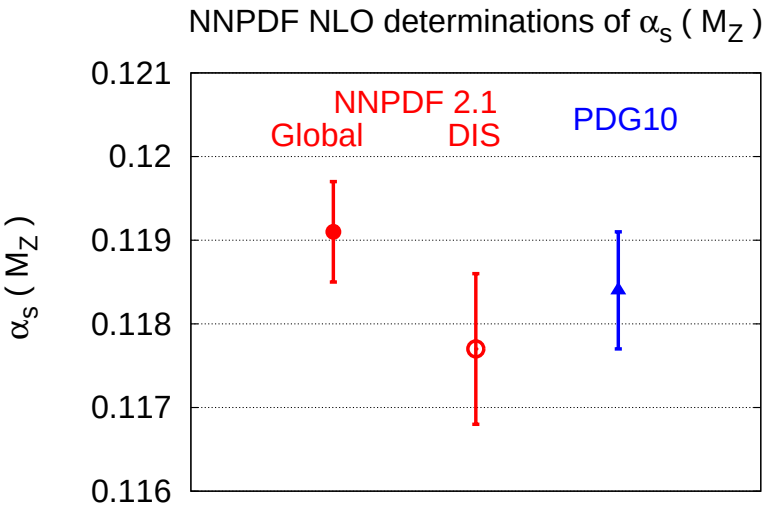


G. Watt 2011

Crucial to provide PDF sets with varying $\alpha_s\,(M_Z)$
This includes $\alpha_s^{\rm PDG}\,(M_Z)$ for reliable LHC phenomenology

Dataset dependence of $\alpha_s(M_Z)$ in PDF fits

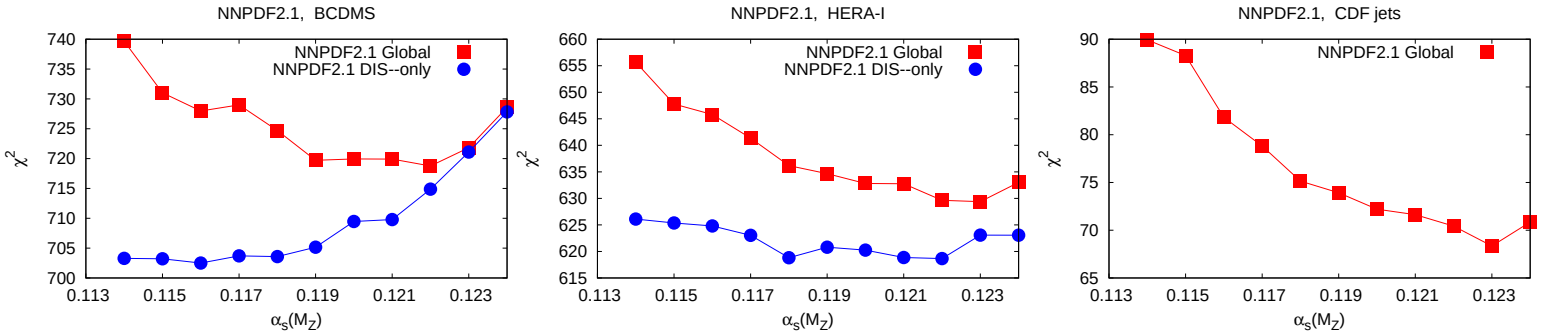
	$\alpha_s(M_Z)$
NNPDF2.1	$\mathbf{0.1191 \pm 0.0006^{stat}}$
NNPDF2.1 DIS–only	$\mathbf{0.1177 \pm 0.0009^{stat}}$
NNPDF2.0	0.1168 ± 0.0007^{stat}
NNPDF2.0 DIS–only	0.1145 ± 0.0010^{stat}



- Do DIS data prefer a smaller value of α_s?
  Perhaps, but not much smaller, compatible with global fit and with higher uncertainties
- Theoretical uncertainties likely dominant (*Ex.* $\Delta\alpha_s^{\rm HQ} \sim 0.002$)

Anyway, this is to be kept separated to which $\alpha_s(M_Z^2)$ should used in LHC phenomenology!

$\alpha_s\,(M_Z)$ for individual experiments



- BCDMS in a DIS–only fit sometimes has runaway direction at small $\alpha_s\,(M_Z)$, absent in the global fit
- HERA rather flat in α_s in DIS–only fit
- Tevatron jet experiments exclude small $\alpha_s\,(M_Z)$ values

Interplay between DIS and hadronic data important

Summary

- NNPDF2.1 NNLO will be ready for LHC phenomenology in a few weeks
- The NNLO Higgs cross section in reasonable agreement with NNPDF2.1 NNLO and MSTW08 (also in DIS–only fit)
- Differences in the treatment of NMC have negligible impact on PDFs and Higgs production within NNPDF
- $\alpha_s(M_Z)$ determined at NLO from NNPDF2.1: compatible with PDG average, reduced statistical uncertainties, theory errors dominant

Thanks for your attention!

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